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LEVELS-OF-GROWING-STOCK STUDY IN THINNED WESTERN LARCH POLE STANDS IN EASTERN OREGON

K.W. SEIDEL

PACIFIC NORTHWEST
FOREST AND RANGE EXPERIMENT STATION
US DEPARTMENT OF AGRICULTURE, FOREST SERVICE
PORTLAND, OREGON

Metric Conversions

1 mile = 1.61 km
1 foot = 0.3048 m
1 inch = 2.54 cm
1 acre = 0.4047 ha
1 square foot per acre = 0.2296 square meters per hectare
1 cubic foot per acre = 0.0700 cubic meters per hectare

Acknowledgment

WALTER G. DAHMS, formerly with the Pacific Northwest Forest and Range Experiment Station and now retired, was responsible for the design and installation of this study.

LEVELS-OF-GROWING-STOCK STUDY IN THINNED WESTERN LARCH POLE STANDS IN EASTERN OREGON

Reference Abstract

Seidel, K. W.
1977. Levels-of-growing-stock study in thinned western larch pole stands in eastern Oregon. USDA For. Serv. Res. Pap. PNW-221, 14 p., illus. Pac. Northwest For. and Range Exp. Stn., Portland, Oregon.

The 10-year growth response from a levels-of-growing-stock study in an even-aged western larch stand in eastern Oregon, first thinned at age 33, showed that trees growing at lower stand densities grew more rapidly in diameter but did not grow faster in height than trees in high density plots. Both basal area and total cubic volume increment increased as stand density increased. Despite the large reduction in volume increment at the lower densities, most of the wood, however, is concentrated on a fewer number of faster growing trees that can reach usable size sooner.

KEYWORDS: Growing stock (-increment/yield, thinnings (-stand volume, stand density, forest improvement cutting, stand improvement, increment (diameter), increment (basal area), increment (stand volume), western larch, Oregon (eastern).

RESEARCH SUMMARY

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A levels-of-growing-stock study was installed in a 33-year-old even-aged western larch stand in 1966 for the purpose of providing basic growth and yield information over a wide range of stocking levels. The study is located in eastern Oregon in a seral larch stand typical of the *Abies grandis*/*Calamagrostis rubescens* plant community. The plots were precommercially thinned from below to five density levels expressed as thousands of square feet of bole area per acre.

Diameter growth was significantly affected by stand density, increasing as growing-stock level decreased. During the 10-year period after thinning, growth increased average stand diameter by 3.4 inches in low density plots compared with a 1.0-inch increase in high density plots. Height growth was insensitive to changes in stand density, and mortality was negligible. Both basal area and total cubic volume increment increased significantly as stand density increased. Although total volume growth was greatest in high density plots, wood is added more rapidly to a smaller number of potentially usable trees in the low density plots. Board-foot growth was greatest in the low density plots because of the large amount of ingrowth from trees reaching merchantable size.

Bole area was found to be a satisfactory measure of stand density. A constant bole area level resulted

in a rising level of basal area as the stand grew older. Basal area and number of trees per acre equivalents for bole area levels are given by average stand diameter for land managers wishing to use bole area as a measure of stand density.

Evidence from other studies suggests that the ideal time for precommercially thinning overstocked larch stands is around 10 to 15 years of age before crowns have begun to shorten and before diameter and height growth is slowed. As demonstrated in this study, however, considerable gains are still possible from precommercial thinnings in larch stands up to 30 years of age and 45 feet tall. The proper intensity of thinning depends not only upon timber management objectives, but also upon the importance to the land manager of other forest resources. In terms of timber management, the primary factor influencing the residual stocking level is the forester's estimate of the minimum size tree (d.b.h.) that will be merchantable in the future. The larger the trees must be to support a commercial thinning, the fewer trees should be left after precommercial thinning; and conversely, if smaller trees are merchantable, the residual stocking should be higher.

Western larch (*Larix occidentalis* Nutt.) is a valuable seral species in the mixed conifer forests of northeastern Oregon because of its fast growth rate and desirable wood properties. Even-aged larch stands generally become established following fire or other forest disturbances. These stands are often heavily overstocked as seedlings.

Stand density control by thinning is an essential part of the management of young larch stands. Because of the shade intolerance of larch, tree crowns in unthinned stands are reduced in size resulting in a decrease in rates of diameter and height growth as early as 9 years of age (Schmidt 1966). The increasing utilization of larch and other species and the associated intensification of forest management raises questions regarding suitable stocking level regimes for managed larch stands.

Although some information is available on the response of larch to thinning from studies in Montana and British Columbia (Roe and Schmidt 1965, Illingworth 1964, Thompson 1969), there is no long-term data on the growth response of managed stands to various growing stock levels. Basic growth and yield data over a rotation is needed so forest managers can design thinning schedules to meet timber production and multiple use objectives.

This paper presents 10-year-growth results from a levels-of-growing-stock study begun in 1966 in northeastern Oregon. The study was designed to provide basic information on the growth response of young even-aged larch stands to a wide range of stocking levels. The first 5-year results from this study were reported by Seidel (1971).

Study Area and Methods

The study is located on the Union District of the Wallowa-Whitman National Forest about 15 miles southeast of Union, Oregon at an elevation of about 4,000 feet. The stand was 33 years old in 1966 and has a site index of about 80 feet at age 50.[1/]

All plots were well stocked before the initial thinning, each containing at least 25,000 square feet of bole area per acre (table 1). There were about 1,300 trees per acre averaging 4.5 inches d.b.h. and 45 feet tall. All plot trees are larch except for one plot at the highest density level and one plot at the second highest level where about 40 percent of the bole area and basal area left after the initial thinning was lodgepole pine (*Pinus contorta* Dougl.).

The soil is a Tolo silt loam, which is a well-drained Regosol developed from dacite pumicite originating from the eruption of Mount Mazama (Crater Lake) 6,500 years ago. It is underlain at a depth of about 3 feet by a buried soil developed from basalt.

Ground vegetation on the study area is typical of the *Abies grandis*/ *Calamagrostis rubescens* plant community (Franklin and Dyrness 1973). Genera of shrubs and herbs such as *Arnica*, *Hieracium*, and *Ribes* are common.

The experiment is a levels-of-growing-stock study designed for thinning at 10-year intervals. The experiment consists of a completely randomized design with two replicates of five levels-of-growing-stock randomly assigned to each of ten 0.4-acre plots. The growing-stock levels selected for testing are 5,000; 10,000; 15,000; 20,000; and

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[1/] Site index based on curves in "Ecology and Silviculture of Western Larch Forests," by Wyman C. Schmidt et al. (1976).

Table 1--*Stand characteristics per acre of western larch before and after the 1966 and 1976 thinnings and in 1971*

Density level	Bole area	Basal area	Number of trees	Average spacing	Quadratic mean diameter	Average height[1]	Volume[2] Total	Volume[2] Merchantable including ingrowth	
	Square feet	Square feet		Feet	Inches	Feet	Cubic feet	Cubic feet	Board feet
Before initial (1966) thinning:									
1	25,800	118.6	924	6.9	4.9	48.4	1,995	1,180	48
2	31,125	132.7	1,161	6.1	4.6	46.2	2,287	1,088	--
3	34,180	139.2	1,406	5.6	4.3	46.5	2,367	885	193
4	32,880	143.7	1,377	5.6	4.4	42.9	2,322	1,125	--
5	32,700	135.6	1,459	5.5	4.1	42.0	2,200	964	--
Average	31,337	134.0	1,265	5.9	4.5	45.2	2,234	1,048	48
After 1966 thinning:									
1	4,708	26.0	96	21.3	7.0	48.4	474	389	48
2	9,524	49.6	215	14.2	6.5	46.2	902	648	--
3	14,242	70.9	355	11.1	6.1	46.5	1,272	782	193
4	19,313	96.4	546	8.9	5.7	42.9	1,616	1,039	--
5	24,203	109.8	745	7.6	5.2	42.0	1,847	961	--
1971:									
1	6,374	40.3	96	21.3	8.8	55.4	794	678	948
2	12,069	68.2	215	14.2	7.6	51.7	1,333	1,060	294
3	17,797	93.4	354	11.1	7.0	53.3	1,780	1,261	532
4	23,810	120.5	539	9.0	6.4	49.1	2,250	1,562	345
5	29,121	134.3	740	7.7	5.8	48.0	2,510	1,435	102
Before 1976 thinning:									
1	8,730	56.3	96	21.3	10.4	62.7	1,222	1,164	3,654
2	15,207	86.1	215	14.2	8.6	56.6	1,870	1,716	2,366
3	21,716	114.8	354	11.1	7.7	58.2	2,471	2,173	1,464
4	29,244	143.9	534	9.0	7.0	55.5	3,103	2,584	1,168
5	33,917	155.7	734	7.7	6.2	53.6	3,317	2,445	706
After 1976 thinning:									
1	5,078	34.2	51	29.2	11.1	--	760	731	2,876
2	10,006	59.3	129	18.4	9.2	--	1,301	1,216	2,368
3	15,012	82.7	225	13.9	8.2	--	1,808	1,627	1,464
4	20,029	104.0	333	11.4	7.6	--	2,248	1,957	1,168
5	24,779	121.0	464	9.7	6.9	--	2,621	2,138	706

[1] Average height of trees measured with dendrometer (about 15 per plot).

[2] Total cubic-foot volume--entire stem, inside bark, all trees.
Merchantable cubic-foot volume--trees 5.0-inch d.b.h. and larger to a 4-inch top d.i.b.
Board-foot volume--International 1/4-inch rule, trees 10.0-inch d.b.h. and larger to a 6-inch top d.i.b.

25,000 square feet of bole area per acre.[2] Corresponding stand densities in terms of basal area are also given (table 1). The two plots assigned to each density level were thinned to the same bole area level in 1966 and 1976.

[2] Bole area is a close approximation of the cambial area of the main stem. See Lexen (1943) and Smith (1962, p. 102) for a discussion of the advantages of bole area as a measure of stand density.

In general, plots were thinned from below to leave the required number of the largest and most vigorous trees as evenly spaced as possible (fig. 1). None of the slash from the thinnings was removed from the plots.

Diameters of all plot trees were measured to the nearest 0.1 inch after the 1965, 1970, and 1975 growing seasons. On each plot, about 15 trees,

Figure 1.--One of the 10,000-square-foot bole area density plots after initial thinning in 1966, with an average spacing of 14 feet. Basal area is about 50 square feet per acre.

proportionately distributed over the range of diameters, were measured with an optical dendrometer in 1966, 1970, and 1975. The measurements were used to calculate an equation expressing volume and bole area of the entire stem inside bark as a function of diameter. The same trees were measured each time. New equations were calculated after each measurement and used to compute plot volumes (cubic feet and board feet, International 1/4-inch rule) at the beginning and end of the two 5-year growth periods. Height growth was measured by dendrometer on trees chosen for volume equation measurements.

Split-plot analyses of variance were used to test significance of treatment effects; and nonlinear regression analyses related diameter, basal area, and volume growth to residual bole area and basal area.

Results

DIAMETER GROWTH

Diameter growth was greatest on the most heavily thinned plots during

both 5-year study periods (table 2). The average growth during the first period declined from 0.36 inch per year at the lowest density level to 0.11 inch per year at the highest density partly because of a larger number of smaller, slower growing trees in the high density plots. During the second period, the diameter growth rate at the lowest density (0.32 inch per year) was four times the growth at the highest density (0.08 inch per year). These differences in diameter growth rate between growing-stock levels were significant (P <0.01).

Diameter growth decreased from the first to the second period at each density level. This difference in growth rate between the two periods was significant (P <0.01) and ranged from 11 percent at the lowest stocking level to 27 percent at the highest. No significant interaction existed between growth periods and growing-stock levels.

A highly significant curvilinear relationship existed between periodic annual diameter increment and stand bole area or basal area at the beginning of each growth period (figs. 2 and 3). Bole area and basal area each explained about 98 percent of the variation in diameter growth between plots during both periods.

During the 10 years of this study, the average stand diameter increased by 6.2 inches in the lowest density plots compared with a 2.8-inch increase in the highest density plots. Tree growth made up about one-third to three-quarters of the diameter increase, and the two thinnings resulted in the additional change (table 3). As a result of removal of smaller trees and faster growth on the residual trees in the lowest density plots, the average diameter in these plots was 61 percent greater in 1976 than in the highest density plots (11.1 vs 6.9 inches) (table 1). Diameter growth of larch and lodgepole pine was similar during both periods.

Diameter growth of the 75 largest trees per acre decreased significantly with increasing stand density in the same manner as growth of all trees (table 2). During the 10-year period, these largest trees grew almost 2 inches more in diameter at the lowest than at the highest density level.

Table 2--*Periodic annual increment and mortality per acre of western larch by age and density level after initial thinning at age 33*

Density level	All trees														75 largest trees	
	Residual density		Diameter growth[1/]	Basal area growth			Total volume growth			Merchantable volume growth including ingrowth			Board-foot ingrowth		Diameter growth[1/]	Gross total volume growth
	Bole area	Basal area		Net	Mortality	Gross	Net	Mortality	Gross	Net	Mortality	Gross				
	Square feet	Square feet	Inches	Square feet	Square feet	Square feet	Cubic feet	Cubic feet	Cubic feet	Board feet	Board feet	Board feet	Board feet	Percent	Inches	Cubic feet
Age 33-38																
1	4,700	26.0	0.36	2.86	--	2.86	64	--	64	180	--	180	170	94.4	0.36	54
2	9,500	50.0	0.23	3.72	--	3.72	86	--	86	59	--	59	59	100.0	0.27	40
3	14,250	71.0	0.18	4.50	.03	4.53	102	1	103	68	--	68	43	63.2	0.24	31
4	19,300	96.0	0.14	4.82	.19	5.01	127	4	131	69	--	69	69	100.0	0.22	30
5	24,200	110.0	0.11	4.90	.17	5.07	133	3	136	22	--	22	22	100.0	0.19	28
Age 38-43																
1	6,400	40.0	0.32	3.20	--	3.20	85	--	85	541	--	541	403	74.5	0.33	73
2	12,100	68.0	0.19	3.58	--	3.58	107	--	107	414	--	414	374	90.5	0.20	48
3	17,800	93.0	0.15	4.28	--	4.28	138	--	138	186	--	186	130	70.2	0.18	48
4	23,800	120.0	0.12	4.69	.16	4.85	170	3	173	164	--	164	125	76.2	0.16	44
5	29,100	134.0	0.08	4.29	.11	4.40	161	2	163	120	--	120	96	80.0	0.14	32

1/ Arithmetic diameter growth of trees living through 5-year periods.

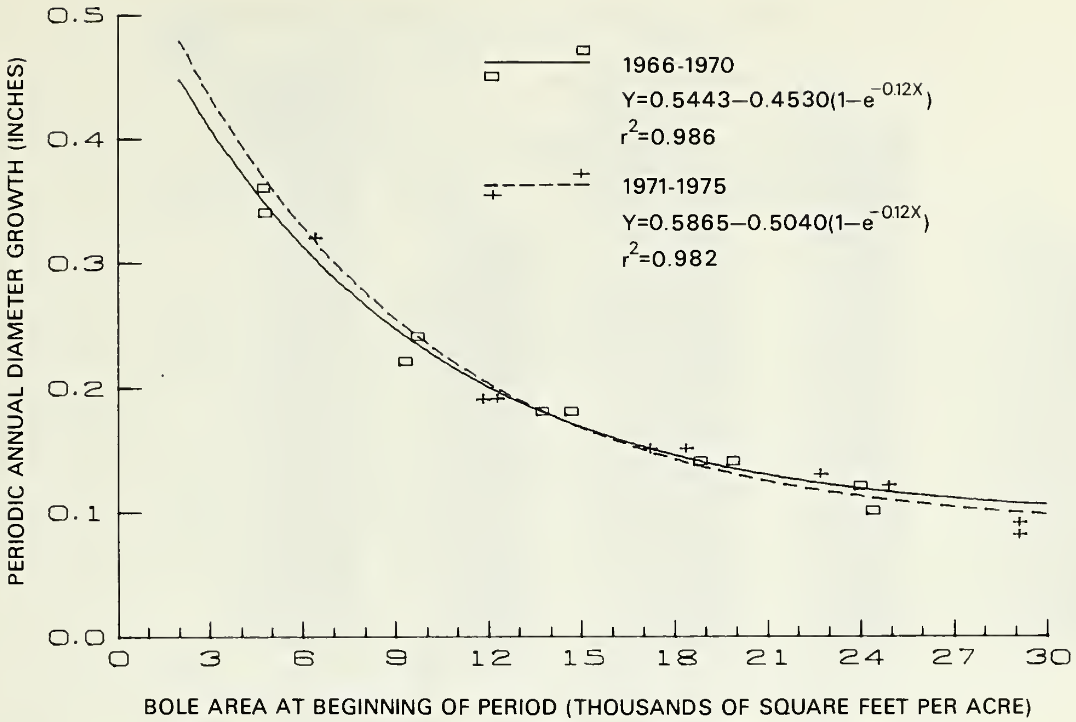

Figure 2.--Periodic annual diameter increment by density level (bole area) and growth period.

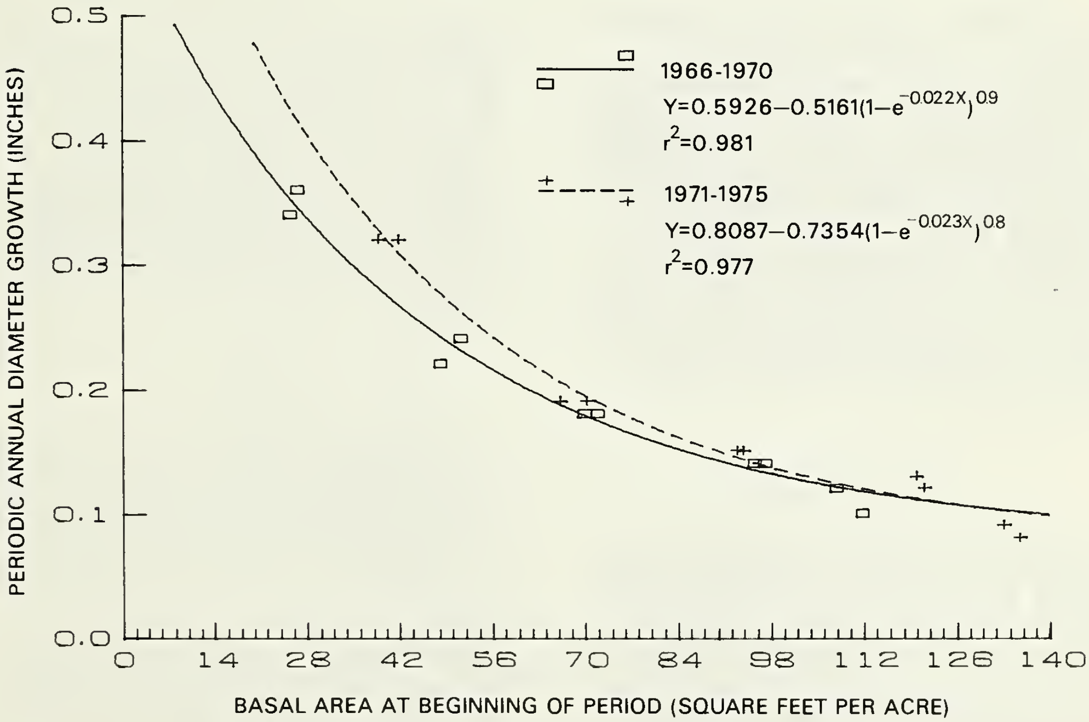

Figure 3.--Periodic annual diameter increment by density level (basal area) and growth period.

Table 3--*Increase in quadratic mean stand diameter from 1966 to 1976 as a result of growth and two thinnings*

Period and bole area level	Increase in average diameter	Increase attributed to:		
		Thinning	Growth	
($M\ ft^2$ per acre)	Inches	Inches	Inches	Percent
1966-70				
5	+3.9	+2.1	+1.8	46
10	+3.0	+1.9	+1.1	37
15	+2.7	+1.8	+0.9	33
20	+2.0	+1.3	+0.7	35
25	+1.7	+1.1	+0.6	35
1971-76				
5	+2.3	+0.7	+1.6	70
10	+1.6	+0.6	+1.0	63
15	+1.2	+0.5	+0.7	58
20	+1.2	+0.6	+0.6	50
25	+1.1	+0.7	+0.4	36
1966-76				
5	+6.2	+2.8	+3.4	55
10	+4.6	+2.5	+2.1	46
15	+3.9	+2.3	+1.6	41
20	+3.2	+1.9	+1.3	41
25	+2.8	+1.8	+1.0	36

Another way to look at diameter growth is to consider growth of individual trees rather than average plot increment. Although, in general, larger trees grew faster than smaller trees, there was only a weak relationship between initial diameter and diameter growth for each period. Regressions of diameter growth on diameter by plot resulted in r^2 values ranging from 0.002 to 0.53 with the best relationship found on high density plots because of a greater range of diameters.

HEIGHT GROWTH

Height growth varied little in response to changes in stand density during both growth periods (fig. 4). Only small differences in growth occurred at the various bole area levels, and there was no indication of any correlation between height growth and stand density. No significant differences were found among density levels and growth periods, and the level-period interaction was not significant. Average increment ranged from 1.0 to 1.4 feet annually and growth of individual trees ranged from 0 to 2.8 feet per year. Larch and lodgepole pine both showed similar rates of height growth during both periods.

MORTALITY

Mortality during the 10 years of this study was negligible. Only 12 of the 1,567 study trees died during the first period and 7 died during the second. All mortality occurred in the two highest density levels except for one tree that died in one of the middle density plots. There was no evidence of larch casebearer (*Coleophora laricella* Hbn.) infestation in any of the plots.

Figure 4.--Periodic annual height increment by density level (bole area) and growth period.

BASAL AREA GROWTH

Basal area increment increased during both periods with increasing stand density (table 2). Differences among density levels were significant ($P < 0.01$). Growth slowed only slightly from the first to second period, but the difference was significant ($P < 0.01$). The interaction between density and growth period was also significant ($P < 0.01$) because of the increase in growth at the lowest density level from the first to second period in contrast to a decrease at the other four levels.

The regressions of basal area increment on bole area and basal area did not depart significantly from linearity within the range of the data (figs. 5 & 6). A curvilinear equation forcing the curve through the origin was selected, however, since increment must be zero at zero stand density. The curves through the origin accounted for about the same amount of variation as those limited to the data range. Bole area and basal area were about equal as predictors of basal area increment.

VOLUME GROWTH

Total gross cubic volume increment was excellent during the 10-year study period, reaching a high of 173 ft^3 per acre annually (table 2). Volume growth increased with rising growing stock level during both periods, and the difference among density levels was significant ($P < 0.01$). Gross cubic

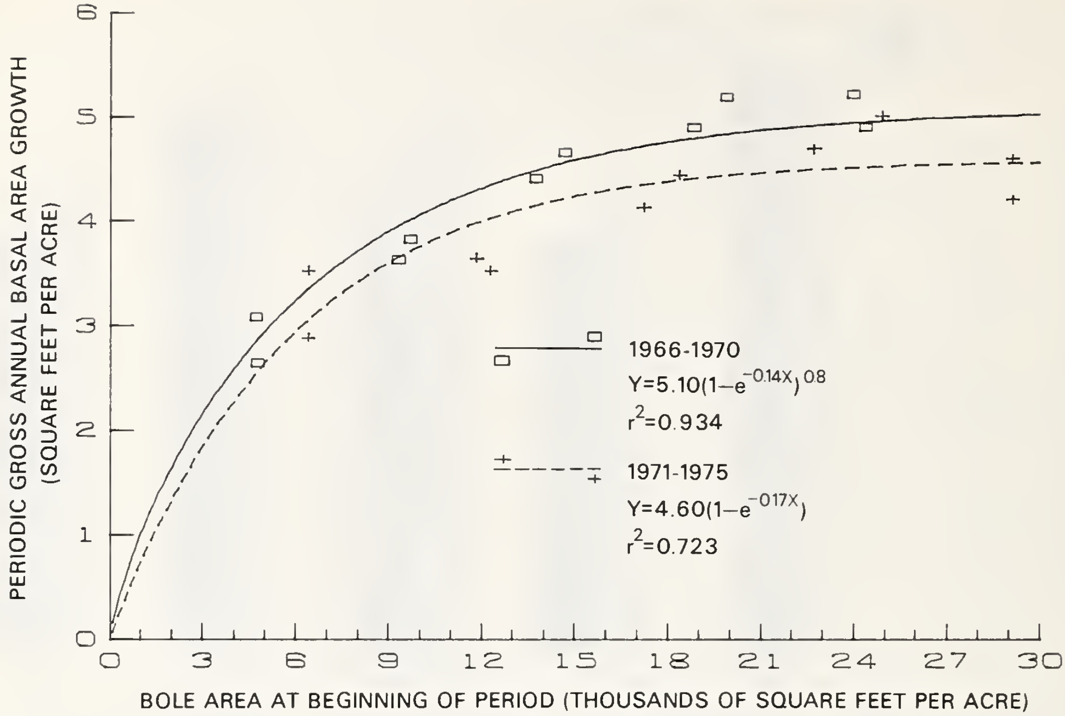

Figure 5.--Periodic gross annual basal area increment by density level (bole area) and growth period.

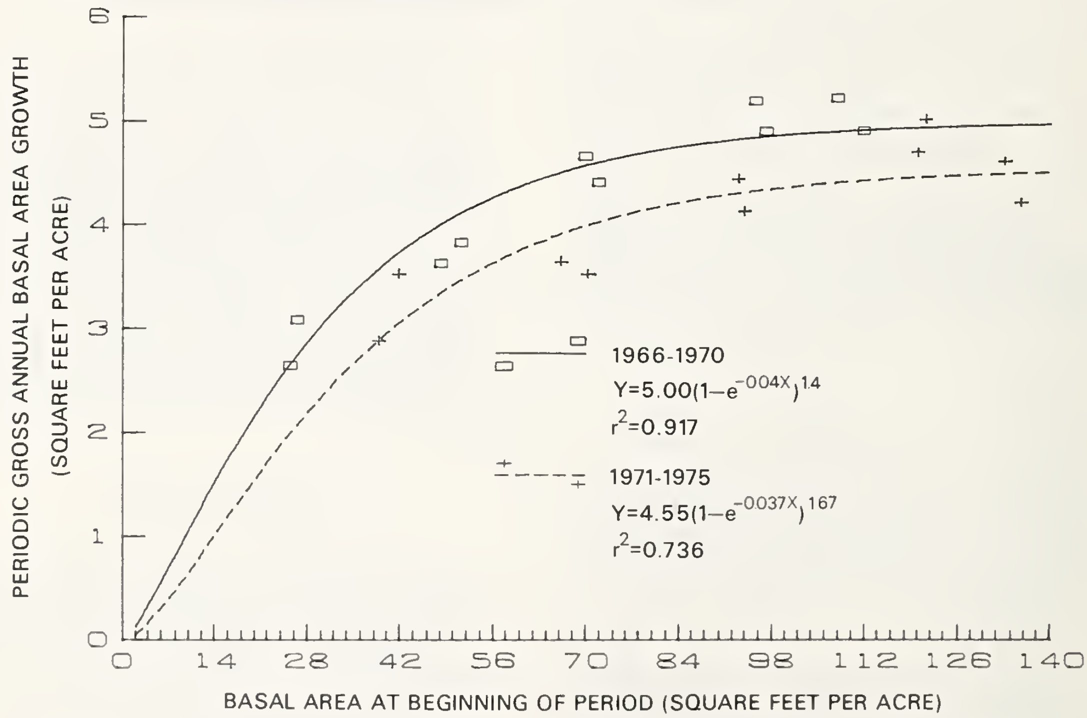

Figure 6.--Periodic gross annual basal area increment by density level (basal area) and growth period.

increment increased significantly ($P < 0.01$) from the first to second period. This difference in growth between the two periods ranged from 20 to 34 percent. No significant interaction was found between growth periods and density levels. Net volume growth was essentially the same as gross because of the small amount of mortality during the study period.

Volume increment was about twice as great on the highest as on the lowest density plots during both periods; but much of this growth at high densities is distributed on a large number of smaller, slower-growing trees. In contrast, concentration of growth on fewer faster growing trees in the heavily thinned plots resulted in 96 trees per acre producing about 50 percent of the cubic volume grown by 745 trees per acre.

The regressions of volume increment on bole area (fig. 7) and on basal area (fig. 8) are similar in terms of the amount of explained variation--accounting for about 84 to 92 percent of the variation in volume increment. Similar to basal area growth, the cubic volume regressions were linear within the range of the data but were forced through zero with only a small reduction in r^2 values. Although these regressions show increased growth with rising stand density, increment was only slightly more at the highest density than at the second highest level during the first period and decreased somewhat during the second period (table 2). This suggests that full site utilization occurs as stand density approaches 25,000 ft^2 of bole area per acre and that increasing stocking beyond this level may not result in an increase in total volume increment.

During the 10-year study period, gross volume growth of the 75 largest trees per acre responded to stand density

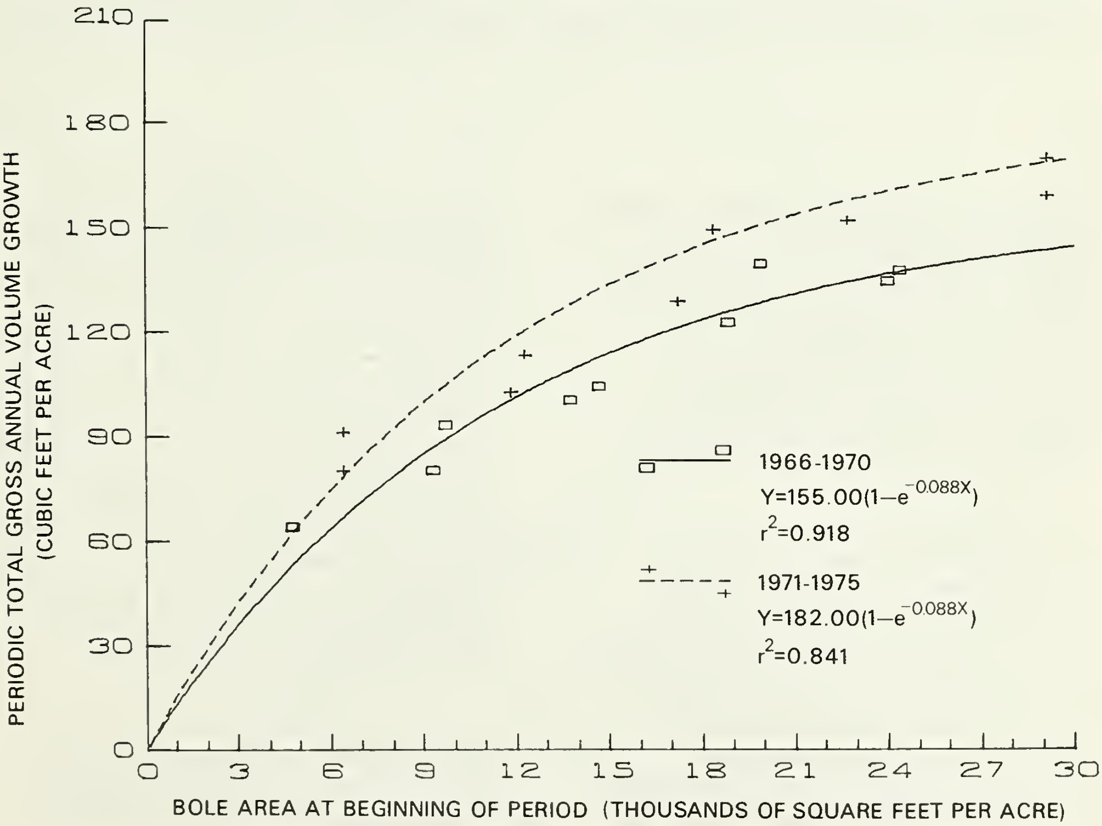

Figure 7.--Periodic total gross annual cubic volume increment by density level (bole area) and growth period.

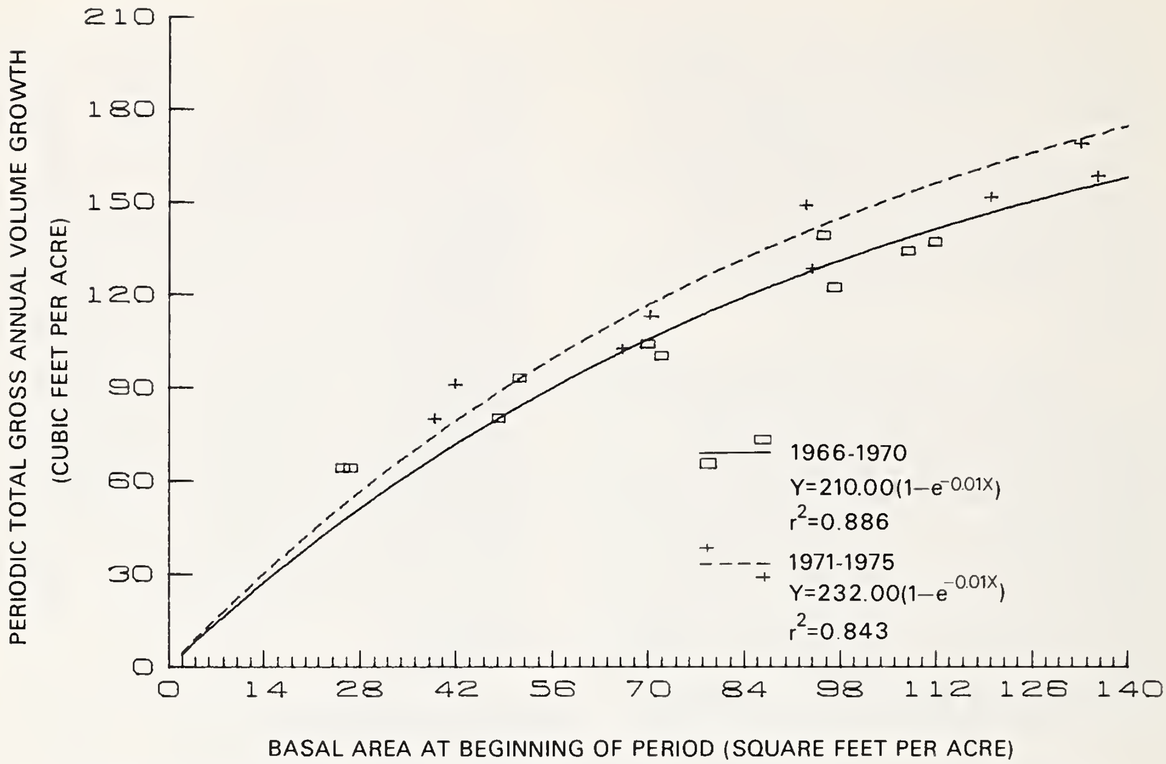

Figure 8.--Periodic total gross annual cubic volume increment by density level (basal area) and growth period.

in the same manner as diameter growth--with greatest growth at the lowest density level (table 2). About twice as much wood has been added to these larger trees at the lowest density level than at the highest. This clearly illustrates the effect of thinning in transferring growth to the larger trees more rapidly in the low density plots.

Board-foot volume increment increased substantially during the second period as compared to the first period; but in young stands such as these, ingrowth still accounts for the largest portion of the board-foot increment (75 to 90 percent during the second period) (table 2). Because of the large variation between plots due to ingrowth, board-foot growth data were not subjected to statistical analyses. It is apparent, however, that board-foot increment was considerably greater at the lowest stocking level and decreased with increasing stand density because of the more rapid diameter growth in low density plots moving more trees into the sawlog class (ingrowth). Board-foot growth in the high density plots should increase rapidly in the future because of the many trees now in or approaching merchantable size classes. No mortality of trees 10.0-inch d.b.h. or larger occurred during either growth period so gross and net board-foot growth are equal.

As might be expected in pole stands, mean annual increment is still increasing at all density levels (table 4). Cubic volume

Table 4--*Net mean annual increment per acre*

Bole area level	Age		
	33	38	43
($M\ ft^2$ per acre)		Cubic feet	
5	60	61	64
10	69	72	76
15	72	76	83
20	70	78	89
25	67	75	85

yields measured on these plots are similar to yield table data for larch in Montana (Schmidt et al. 1976). If this similarity continues, culmination of mean annual increment will occur at about 60 to 70 years of age.

BOLE AREA-BASAL AREA RELATIONSHIPS

Bole area was selected as the measure of stand density in this study since a given bole area was thought to represent a more or less constant level of competition over time in contrast to basal area which, for a given level of competition, increases with age and average diameter. Therefore, it was expected that maintaining a constant bole area level by thinning as the stand grows older should result in a rising level of basal area; this occurred during the 10 years of observation of the present study. Because of the more rapid rate of change of basal area relative to bole area, basal area increased with stand age for any given bole area level (fig. 9). For example,

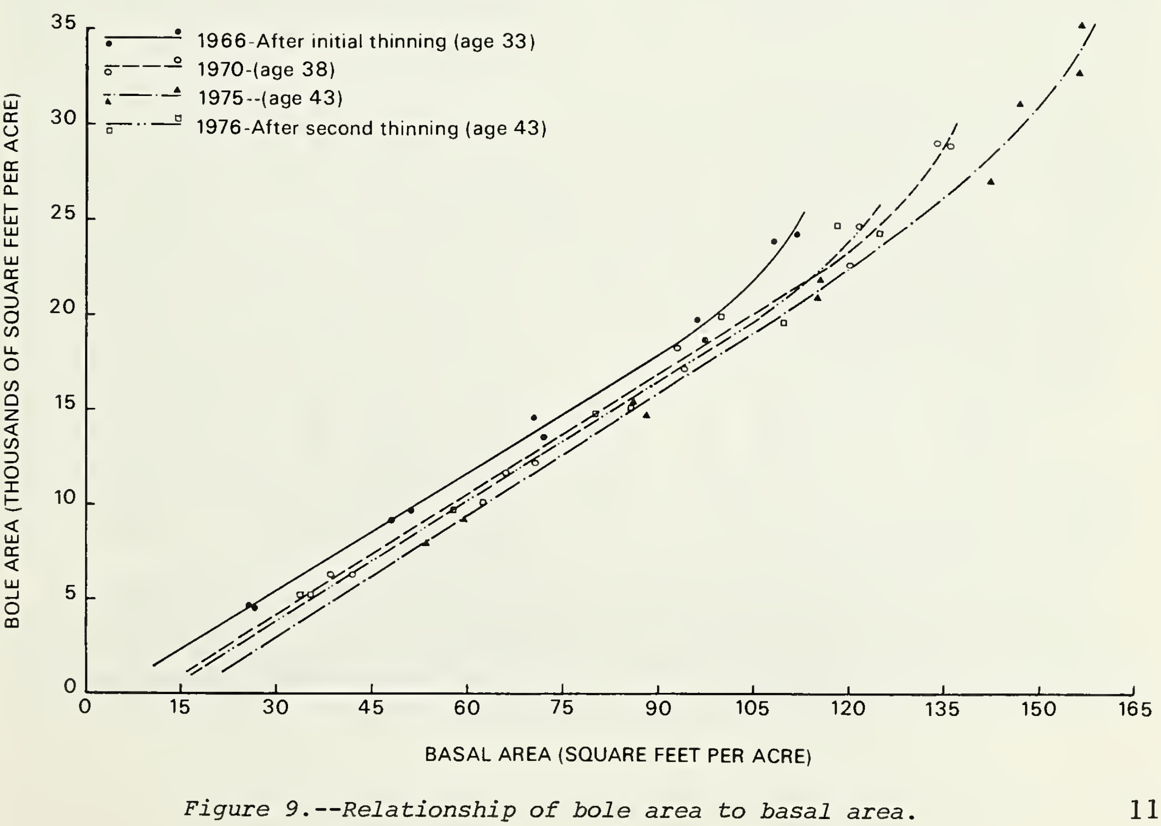

Figure 9.--Relationship of bole area to basal area.

in 1966 at age 33, a basal area density of about 51 ft^2 per acre was equivalent to a bole area density of 10,000 ft^2 per acre. After the second thinning in 1976 reduced bole area levels to their initial values, the degree of competition indicated by the 10,000 ft^2 per acre bole area level was now equal to about 60 ft^2 per acre of basal area; an increase of about 9 ft^2 per acre over the basal area value after the initial thinning.

Although bole area appears to be a more stable measure of stand density than basal area, it is not well suited for routine use in the field because it is a function of diameter, height, and stem taper. For foresters interested in using bole area in thinning prescriptions, I have expressed bole area in terms of more easily used measures--basal area and number of trees by various stand diameters (table 5). For example, in order to maintain a bole area density of 15,000 ft^2 per acre, basal area should rise from 36 to 99 ft^2 per acre as average stand diameter increases from 2 to 10 inches.

I want to emphasize that the bole area-basal area relationships given here were derived from data obtained in high-site larch plots and are not intended to be representative over the entire range of site classes. Also, these data should not be extrapolated to larger diameter classes because of changing diameter, height, and form relationships which are likely to occur. Finally, the data shown in table 5 are not to be considered as a thinning schedule or recommended stocking level guide. They are only an estimate of the basal area or number of trees needed per acre to maintain a more or less constant bole area level over time for a limited range of diameter classes.

Discussion

It is evident from the 10-year growth data that thinning has effectively concentrated growth on a small number of crop trees in the low density plots. The volume growth rate of the 75 largest trees per acre at the lowest stocking level was about twice as great as an equal number of largest trees at

Table 5--*Number of trees and basal area per acre by bole area and average stand diameter*[1/]

Average stand diameter	Bole area--thousands of square feet									
	5		10		15		20		25	
	Number of trees	Basal area	Number of trees	Basal area	Number of trees	Basal area	Number of trees	Basal area	Number of trees	Basal area
Inches		Sq. ft.		Sq. ft.		Sq. ft.		Sq. ft.		Sq. ft.
2	556	12	1,111	24	1,667	36	2,222	48	2,778	61
4	205	18	410	36	615	54	820	72	1,025	89
6	119	23	238	47	357	70	476	93	595	117
8	81	28	162	57	244	85	325	113	406	142
10	60	33	121	66	181	99	242	132	302	165
12	47	37	95	74	142	112	190	149	237	186
14	39	41	77	82	116	124	154	165	193	206
16	32	45	65	90	97	135	129	180	161	225

[1/] Limits of basic plot data enclosed within solid line. Values in table were derived as follows: (1) the bole area equations expressing bole area as a function of diameter in 1966, 1970, and 1975 were used to calculate three bole area values per tree for each of the diameter classes, (2) a mean bole area per tree for each diameter class was found, (3) the mean bole area per tree for each diameter class was divided into each bole area level to obtain the number of trees per acre for that diameter class, and (4) basal area per tree for each diameter class was multiplied by trees per acre to obtain basal area per acre.

the highest density level. And the average diameter of trees in the low density plots was 11.1 inches in 1976, an increase of 4.2 inches over the average diameter found in the high density plots.

Because of the linear trend of volume increment on stand density, each reduction in growing stock resulted in a decrease in volume growth. Therefore, if markets for small trees exist and frequent commercial thinnings are possible to utilize mortality, a high residual stand density is indicated to more fully utilize the productive capacity of the site and maximize wood production. If, on the other hand, no pulpwood market exists and the management objective is to increase water and forage yields, precommercial thinning is necessary to eliminate the overstocked conditions existing in many natural larch stands.

Obviously, decisions concerning stocking levels after precommercial thinning should consider not only timber management objectives but also the relative importance of other forest resources to the land manager. The primary timber management objective of precommercial thinning is to stimulate diameter growth rate of residual trees so merchantable products may be harvested sooner. Thus, the stocking level left after precommercial thinning depends upon the land manager's estimate of the minimum size tree (d.b.h.) that will be merchantable in the future. By leaving a high stand density level after precommercial thinning, a forester is assuming that smaller trees will support a commercial thinning in the future; and conversely, a low residual stand density implies that larger trees are needed for a commercial thinning.

In a shade intolerant species such as western larch, early thinning should have a high priority. Competition in young, overstocked larch stands results in crown reduction with subsequent decreases in diameter and height growth. In addition, small, low-vigor trees are not as resistant to damage from wind, snow, insects, and diseases as trees having adequate growing space. Studies in Montana by Schmidt (1966) and in Holland by Dik (1975) suggest that the ideal time for precommercial thinning occurs when trees are about 10 years old and from 10 to 15 feet tall. This is similar to the time of thinning recommendations for Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) given by Reukema (1975).

Although the greatest benefits from precommercial thinning occur in young 10- to 15-year-old stands before crowns begin to shorten, considerable gains are still possible from precommercial thinning, as demonstrated in this study, in larch stands up to 30 years of age and 45 feet tall. The younger stands, however, should be given preference for precommercial thinning.

The major conclusions reached after 10 years of growth are:

1. Growth response to stocking level control resulted in less total cubic volume increment per acre but greater diameter and volume growth of individual trees as stand density decreased.

2. Precommercial thinning in these young pole stands concentrated growth on crop trees thus shortening the time until a commercial thinning is possible.

3. Losses from mortality were not a problem in the plots thinned from below even at the highest density level.

Literature Cited

Dik, E. J.
1975. Dunningsproeven in jonge lariksopstanden (Experiments with pre-commercial thinnings in young larch stands) Nederlands Bosbouw Tijdschrift 47(5):139-148.

Franklin, Jerry F., and C. T. Dyrness.
1973. Natural vegetation of Oregon and Washington. USDA For. Serv. Gen. Tech. Rep. PNW-8, p. 195-199. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.

Illingworth, K.
1964. Crop-tree thinning of western larch. B.C. For. Serv. Res. Rev. for 1964, p. 52.

Lexen, Bert.
1943. Bole area as an expression of growing stock. J. Forest. 41:883-885.

Reukema, Donald L.
1975. Guidelines for precommercial thinning of Douglas-fir. USDA For. Serv. Gen. Tech. Rep. PNW-30, 10 p., Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.

Roe, Arthur L., and Wyman C. Schmidt.
1965. Thinning western larch. USDA For. Serv. Res. Pap. INT-16, 10 p. Intermountain For. and Range Exp. Stn., Ogden, Utah.

Schmidt, Wyman C.
1966. Growth opportunities for young western larch. USDA For. Serv. Res. Note INT-50, 4 p., Intermountain For. and Range Exp. Stn., Ogden, Utah.

Schmidt, Wyman C., Raymond C. Shearer, and Arthur L. Roe.
1976. Ecology and silviculture of western larch forests. USDA Tech. Bull. 1520, 96 p.

Seidel, K. W.
1971. Growth of young even-aged western larch stands after thinning in eastern Oregon. USDA For. Serv. Res. Note PNW-165, 12 p., Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.

Smith, David Martyn.
1962. The practice of silviculture. 7th ed., p. 578. John Wiley & Sons, Inc., New York.

Thompson, C. F.
1969. Crop-tree thinning of western larch. B.C. For. Serv. Res. Rev. for 1969, p. 94.

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Seidel, K. W.
1977. Levels-of-growing-stock study in thinned western larch pole stands in eastern Oregon. USDA For. Serv. Res. Pap. PNW-221, 14 p., illus. Pac. Northwest For. and Range Exp. Stn., Portland, Oregon.

The 10-year growth response from a levels-of-growing-stock study in an even-aged western larch stand in eastern Oregon, first thinned at age 33, showed that trees growing at lower stand densities grew more rapidly in diameter but did not grow faster in height than trees in high density plots. Both basal area and total cubic volume increment increased as stand density increased. Despite the large reduction in volume increment at the lower densities, most of the wood, however, is concentrated on a fewer number of faster growing trees that can reach usable size sooner.

KEYWORDS: Growing stock (-increment/yield, thinnings (-stand volume, stand density, forest improvement cutting, stand improvement, increment (diameter), increment (basal area), increment (stand volume), western larch, Oregon (eastern).

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